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Original Article

Morphological Diversity of Wild Populations of *Sarotherodon Melanotheron* Rüppell, 1852 of Southern Benin

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Abstract

The establishment of morphological identity of a species in differently located waterways is very important in the use of its fishery resources in breeding programs. This work aims to analyse the morphological parameters of native populations of *Sarotherodon melanotheron* in relation with their waterway of origin, hydrobiological period and sex. Most of the sampled fishes has sizes ranged between 05 and 15 cm with 57.66%, 31.85%, 36.62% and 22.19% respectively in Grand-Popo lagoon, lake Nokoué, Ouémé river and lake Toho. Outside of the body height, prepelvic length and anal-fin base length, all the other metric parameters varied significantly from a waterway to another ($p<0.05$). For both females and males, the relative growth coefficients (b) varied from 1.74 to 3. The condition factor (K) varied from 1.81±0.37 to 1.88±0.42 and 1.79±0.29 to 1.87±0.36 respectively for males and females and did not vary significantly according to the sex ($p>0.05$). Metric variables were more discriminative than meristic counts. Two populations are differentiated: the first constituted by individuals of Ouémé river and lake Nokoué and the second represented by individuals of Grand-Popo lagoon and lake Toho. Molecular prospectings are necessary to clarify the diversity of this fish.

Keywords: *Sarotheron melanotheron*, morphometric characteristics, hydrobiological period, condition factor, Benin.

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Introduction

In Benin, fisheries production is essentially provided by the fishing in the waterways (Sohou *et al.*, 2009). The fisheries sector, as an essential component of the rural development, appears like strategic to encourage a sustained growth of the Beninese economy (FAO, 2008). Indeed, it plays a non-negligible role in the national economy while contributing notably to the unemployment reduction and satisfaction of the populations' protein needs. The fisheries sector generates more than 600,000 direct and indirect jobs in the country (FAO, 2008). However, since some years, the fish needs of the populations did not stop increasing whereas captures in the waterways fall from year to year. From 2003 to 2008, this fall has been valued to about 15% (MAEP/JICA, 2009). The total quantity of fish products is valued to about 46,491.90 tons in 2013 (CountryStat, 2016). This quantity is insufficient to cover the populations' annual need in fish which is estimated to over 90,000 tons (MAEP/JICA, 2009). To bridge this deficit, in 2013, Benin imported about 73,577.21 tons of fishing products mainly represented by fish (CountryStat, 2016). This dependence on fisheries products importing constitutes a big threat for food security and a loss of currencies for the country.

Facing this situation, aquaculture appears like the only viable alternative for the fishery production increasing in the goal to satisfy the protein needs of the populations (FAO, 2014). Today, fish farming is oriented essentially toward the breeding of tilapia (tilapia farming) and Cat-fish in the traditional fish holes, ponds, enclosures and cages (Ouattara *et al.*, 2003; Sohou *et al.*, 2009). Among these farms, tilapia farming is of a fundamental importance because since 1980, it knew a continuous and relevant growth rate. Tilapia farming becomes the type of aquaculture the most practiced in Africa (FAO, 2012; FAO, 2014). In Benin, tilapia breeding is more oriented toward *Oreochromis niloticus* which despite its aquacultural potentials in fresh waters doesn't tolerate hypersaline environments. However, *Sarotherodon melanotheron* whose aquacultural potentialities has been demonstrated in the West Africa lagoons and estuaries, tolerates better the water salinity than *Oreochromis niloticus* (Ouattara *et al.*, 2003; Ouattara *et al.*, 2005; Ouattara *et al.*, 2009). *Sarotherodon melanotheron* is a West and central African native tilapia species (Adépo-Gourène and Gourène, 2008). It is especially adapted to estuaries and brackish waters and is recovered along the West African coast, from Senegal to Congo (Paugy *et al.*, 2004). Thus, it can be used for fish farming in the areas where fresh waters are rare (Ouattara *et al.*, 2014).

For a better use of *Sarotheron melanotheron* in aquaculture, it is important to value the morphological and genetic identity of the locally available populations (or strains). The establishment of the taxonomic identity of a species in differently located waterways is very important in the use of its fishery resources because the quality of the existing strain is very crucial for any successful breeding programme (Omoniyi and Agbon, 2008).

The knowledge of the diversity of these strains constitutes a previous to the sustainable improvement of the fish production (Toguyeni *et al.*, 2003). Moreover, ecological variations are important in the structuring of natural populations (Crispo and Chapman, 2008) and the variation of some morphometric characters is phenotypic (Adépo-Gourène and Gourène, 2008). However, the morphological divergences observed between strains are generally sustained by genetic differentiations (Toguyeni *et al.*, 2003; Adépo-Gourène and Gourène, 2008).

The present study aims to analyse the morphological patterns of the native populations of *Sarotheron melanotheron* in relation with their waterway of origin, hydrobiological period of sampling and sex in the goal of promoting their farming.

Materials and Methods

Area of Study

The study has been achieved from May to August 2013 in Grand-Popo lagoon, lake Nokoué, Ouémé river and lake Toho in Southern Benin (Table 1). The Ouémé river and lake Toho are fresh waterways while Grand-Popo lagoon and lake Nokoué are brackish waterways. These are the main waterways of the hydrographic basins of Southern Benin (Figure 1).

Table 1: Characteristics of sampling sites.

Waterway	Site	GPS Co-ordinates		Climatic zone	Vegetation cover	Aquatic vegetation
Grand-Popo Lagoon	Gbèkon	06°16'55.8"N	001°50'33.0E	Subequatorial	Grassy savanna	Abundant
	Gbeffa	06°17'01.8"N	001°50'51.0"E	Subequatorial	Grassy savanna	Abundant
	Hêvê	06°16'59.0"N	001°50'40.2"E	Subequatorial	Grassy savanna	Abundant
Lake Nokoué	Abomey-Calavi	06°26'54.0"N	002°21'57.0"E	Equatorial	Grasslands	Scarce
	Ganvié	06°27'41.6"N	002°23'16.9"E	Equatorial	Grasslands	Scarce
	So-Ava	06°29'30.3"N	002°23'55.7"E	Equatorial	Grasslands	Scarce
Lake Toho	Logbo	06°37'02.6"N	001°46'03.5"E	Subequatorial	Guinean forest-savannas	Scarce
	Douimè	06°37'33.1"N	001°46'59.0"E	Subequatorial	Guinean forest-savannas	Abundant and diverse
	Kpinnou	06°36'36.3"N	001°46'21.8"E	Subequatorial	Guinean forest-savannas	Abundant and diverse
Ouémé River	Agonlinlowé	06°39'54.0"N	002°28'57.0"E	Equatorial	Grasslands	Scarce
	Hêtin-Sota	06°35'41.6"N	002°30'16.9"E	Equatorial	Grasslands	Abundant and diverse
	Avagbodji	06°31'30.3"N	002°31'55.7"E	Equatorial	Grasslands	Abundant and diverse

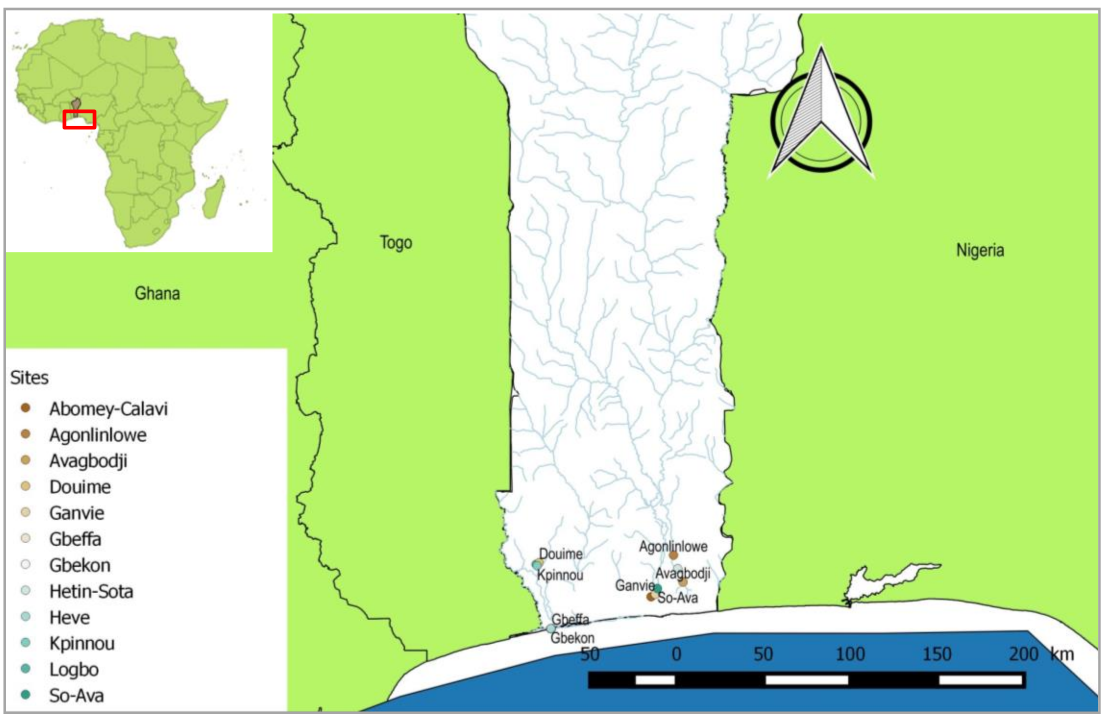

Fig. 1: Map of Southern Benin's hydrographical network, showing the geographical location of the sampling sites.

Assessment of the Water Quality

Physicochemical parameters of water were recorded monthly at 7 a.m. and 5 p.m. in the 4 waterways. Water conductivity, pH, temperature and salinity were monitored directly using a portable multimeter (Hanna®), the dissolved oxygen using a DO meter (Horiba®) and the TDS by a TDS meter (Hanna®). A Secchi disk has permitted to record water transparency.

Morphometric Measurements and Meristic Numberings

A total of 609 *Sarotherodon melanotheron* individuals (Table 2) were sampled at random with fishermen at the 4 waterways during 4 campaigns (one campaign per month). The sampled captures are those of local fishermen using gill nets, cast nets, keep nets, fish hooks and long lines. Two sampling campaigns have been done during the rise of the water level and two other during subsidence. Morphometric measurements (Figure 2) and meristic counts were recorded on each individual according to Stiassny *et al.*, (2007); Adépo-Gourène and Gourène (2008); Dunz and Schliewen (2010). For each specimen, 17 measurements have been recorded (Table 3). The 10 meristic characters analysed are: dorsal-fin rays (DFR), dorsal-fin spines (DFS), anal-fin rays (AFR), anal-fin spines (AFS), upper lateral line scales (ULLS), lower lateral line scales (LLLS), pre-dorsal scales (PrDS), around caudal peduncle scales (CPS), operculum scales (OpS), first branchial arc's upper and lower gill rakers (ULGR). The sampled fish are weighed individually using an electronic balance (Ohaus®, precision: 0.1 g). If necessary, they are then eviscerated for sex determination.

Table 2: Number of sampled individuals per waterway.

Hydrographic basin	Waterways	Number of individuals sampled
Ouémé	Ouémé river	126
	Lake Nokoué	180
Mono	Grand-Popo lagoon	138
	Lake Toho	165
Total		**609**

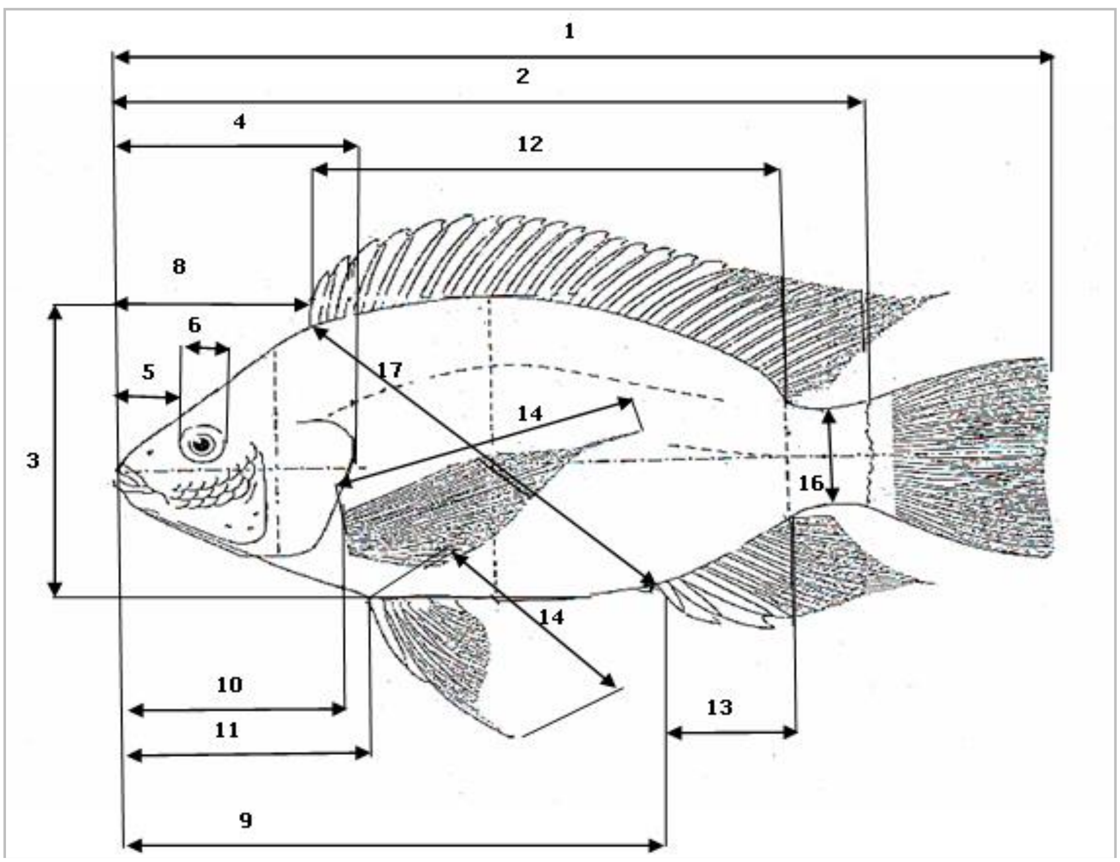

Fig. 2: Schematic illustration of the measurements realized on each individual according to Paugy *et al.*, (2004).

Table 3: Measurements done on each specimen and their descriptions.

Number	Parts	Designation	Abbreviation	Definition
1	Body	Total Length	TL	Horizontal distance from front tip of snout to hind tip of caudal fin
2	Body	Standard Length	SL	Horizontal distance from front tip of snout to base (or articulation) of caudal fin
3	Body	Body Height	BH	Maximum vertical depth of fish, excluding fins
4	Head	Head Length	HL	Horizontal distance from front tip of snout to hind margin of gill cover, or the horizontal distance from front tip of snout to hind tip of occiput or to bony rim of the notch formed by the scapular girdle behind the head.
5	Head	Snout Length	SnL	Horizontal distance from front tip of upper jaw to anterior margin of eye.
6	Head	Eye Diameter	ED	Horizontal diameter of eye.
7	Head	Interorbital Width	IoW	Horizontal distance separating the two ocular orbits
8	Fin	Predorsal Length	PrDL	Horizontal distance from front tip of snout to the articulation of first dorsal-fin ray.
9	Fin	Preanal Length	PrAL	Horizontal distance from front tip of snout to the articulation of the first anal-fin ray.
10	Fin	Prepectoral Length	PrPL	Horizontal distance from front tip of snout to the articulation of the first pectoral-fin ray.
11	Fin	Prepelvic Length	PrPeL	Horizontal distance from front tip of snout to the articulation of the first pelvic-fin ray.
12	Fin	Dorsal-fin baseLength	DL	Maximal horizontal distance measured between both ends
13	Fin	Anal-fin base Length	AL	See dorsal-fin base
14	Fin	Pectoral-Fin Length	PFL	Length from articulation of the first ray to tip of longest ray
15	Fin	Pelvic-Fin Length	PeFL	See pectoral-fin length
16	Stalk	Caudal Peduncle Height	CPH	Minimum vertical depth of caudal peduncle
17	Body	Dorso-Anal Length	DAL	Vertical distance from the superior extremity of the dorsal fin to the lower extremity of the anal fin

Relationships between Total Length and Weight (TL-W), Standard Length and Body Height (SL-BH) and Condition Factor

The Total length-Weight relationships have been established using the equation:

$W = aTL^b$ (Le Cren, 1951),

Where:

W = total weight (g),

TL = total length (cm),

a = the fish environment coefficient and

b = relative growth coefficient.

The standard length-body height (SL-BH) relationships have been described by the equation:

SL = aBH + b,

Where:

SL = standard length (cm),

BH = body height (cm),

b = slope,

a = intercept.

The condition factors were computed for each individual using the equation: $K = 100\ W.TL^{-3}$ (Tesch, 1971), Where: K = relative condition factor, W = total weight (g), TL = total length (TL cm).

Statistical Analysis

Averages of physicochemical, morphometric and meristic characteristics were calculated by the *summary* procedure of R software (http://cran.r-project.org). The F test has been used to determine the significance of each effect (hydrobiological period and time of the day for physicochemical parameters; and hydrobiological period, waterway and sex for the morphological parameters) and averages have been compared two by two using the t test of Student after checking of the normality distribution and variances homogeneity. Correlations, on one hand, between physicochemical parameters and, on the other hand, between morphological parameters have been computed by the *cor* procedure of R. The significance of each correlation was estimated by the *cor.test* procedure of R. The Factorial Correspondences Analysis (FCA) of physicochemical, morphometric and meristic data has been achieved using the *CA* procedure of R. The *hclust* method of R was used to achieve the Numeric Classification (NC). The accuracy of each linear relationship has been estimated using the *lm* procedure of R.

Results

Water Quality based on Physicochemical Parameters

When taking into account the time of the day, for Grand-Popo lagoon, out of the dissolved oxygen and temperature, all the other physicochemical parameters didn’t significantly vary according to the time of the day (Table 4). In the lake Nokoué, the pH, transparency, salinity and TDS didn't vary significantly according to the time of the day. On the other hand, the conductivity, dissolved oxygen and temperature have been higher in the evening than in morning ($p<0.05$). In the Ouémé river and lake Toho, none of the physicochemical parameters varied significantly according to the time of the day (Table 4).

Taking into account the hydrobiological sampling period, at Grand-Popo lagoon, the conductivity, pH, dissolved oxygen, temperature, salinity and TDS didn't vary significantly according to the hydrobiological period of collection. On the other hand, the transparency has been higher ($p<0.01$) during the subsidence than during the rise of the water level.

In the Ouémé river, the pH, temperature and transparency didn't vary significantly according to the period of collection. However, the conductivity, salinity and TDS have been higher during the subsidence than during the rise of the water level ($p<0.001$). An opposite tendency has been observed for the dissolved oxygen rate (Table 4). In lake Nokoué, only the salinity varied significantly from one period to another ($p<0.01$). In lake Toho, only the temperature varied significantly according to the sampling period. Indeed, it has been higher during the subsidence than during the rise of the water level ($p<0.01$).

Multivariate Analysis of Physicochemical Parameters

FCAs and NCs (Figures 3 & 4) have been achieved on physicochemical factors in order to analyse the possible proximities between the 4 waterways. In the morning, percentages of the variance decreased suddenly with the first axis explaining 89.05% of the variations between waterways, the second axis 8.76% and the third 2.20%, in other word, a total of 100% for all the 3 axis. On the axis 1, the temperature, transparency and TDS allowed to bring nearer lake Nokoué to Ouémé river and to move them away from Grand-Popo lagoon. On the axis 2, the conductivity and salinity permitted to move away lake Toho to the 3 other waterways (Figures 3A & 4A). In the evening, percentages of the variance have also decreased suddenly with the first axis explaining 82.94% of the variations between waterways, the second axis 11.47% and the third 5.59%. On the axis 1, the conductivity, temperature, salinity and TDS permitted to separate lake Nokoué from lake Toho. On the axis 2, the dissolved oxygen has allowed to move away Ouémé river from the 3 other waterways (Figures 3B & 4B).

Distribution of Sampled Individuals by Class of Sizes

Structures by size of *Sarotherodon melanotheron* individuals per waterway showed that the majority of the captured individuals was small sizes. The modal class was from 10 to 15. Most of the sampled fish has a size ranged between 10 and 15 cm with 57.66%, 31.85%, 36.62% and 22.19% respectively in Grand-Popo lagoon, lake Nokoué, Ouémé river and lake Toho (Figure 5).

Table 4: Variation of physicochemical parameters per waterway according to the time of the day (1) and the hydrobiological period (2).

(1)

Variable	Grand-Popo lagoon					Lake Nokoué					Ouémé river					Lake Toho				
	Morning		Evening		ANOVA	Morning		Evening		ANOVA	Morning		Evening		ANOVA	Morning		Evening		ANOVA
	M	SE	M	SE		M	SE	M	SE		M	SE	M	SE		M	SE	M	SE	
Conductivity (µs/cm)	12.6a	6.83	6.3a	6,83	NS	7.8b	0.27	8.86a	0.27	*	8.0a	0.1	8.0a	0.1	NS	1.95a	1.36	5.50a	1.4	NS
pH	8.93a	0.05	9a	0.05	NS	8.2a	0.11	8.55a	0.11	NS	7.95a	0.18	8.25a	0.18	NS	8.15a	0.35	8.35a	0.35	NS
Dissolved oxygen (mg/l)	7.51b	0.26	8.39a	0.26	*	4.07b	0.57	8.05a	0.57	**	6.44a	0.73	6.14a	0.73	NS	3.02a	1.59	6.68a	1.59	NS
Temperature (°C)	27.4b	0.82	28.23a	0.82	*	26.13b	0.88	29.45a	0.88	*	27.95a	0.78	28.5a	0.78	NS	27.38a	0.88	28.5a	0.88	NS
Transparency (cm)	42.5a	13.62	42.5a	13.62	NS	21.25a	2.9	22.5a	2.9	NS	32.5a	2.5	27.5a	2.5	NS	49.5a	2.96	48.3a	2.96	NS
Salinity (mg/l)	0.63a	0.35	0.3a	0.35	NS	2.36a	0.64	2.42a	0.64	NS	0.04a	0.01	0.04a	0.01	NS	0.08a	0.16	0.3a	0.16	NS
TDS (ppm)	623a	358	402.5a	357.97	NS	10	0	10	0	NS	40a	10	40a	10	NS	110a	1.77	108a	1.77	NS

(2)

Variable	Grand-Popo lagoon					Lake Nokoué					Ouémé river					Lake Toho				
	Rise of the water level		Subsidence			Rise of the water level		Subsidence			Rise of the water level		Subsidence			Rise of the water level		Subsidence		
	M	SE	M	SE	ANOVA	M	SE	M	SE	ANOVA	M	SE	M	SE	ANOVA	M	SE	M	SE	ANOVA
Conductivity (µs/cm)	15.5a	5.39	17.36a	5.39	NS	8.33a	0.41	8.33a	0.41	NS	7.0b	0	9.0a	0	***	2.23a	1.46	5.23a	1.46	NS
pH	8.9a	0.05	9.03a	0.05	NS	8.28a	0.14	8.48a	0.14	NS	8a	0.21	8.2a	0.21	NS	8.68a	0.25	7.82a	0.25	NS
Dissolved oxygen (mg/l)	8.03a	0.36	7.87a	0.36	NS	6.54a	1.25	5.58a	1.25	NS	7.02a	0.16	5.56b	0.16	*	4.88a	1.91	4.82a	1.91	NS
Temperature (°C)	26.86a	0.67	28.7a	0.68	NS	27.43a	1.29	28.15a	1.29	NS	27.5a	0.32	28.95a	0.32	NS	26.53b	0.47	29.3a	0.47	**
Transparency (cm)	22.5b	7.22	62.5a	7.22	**	24.5a	2.5	19.25a	2.5	NS	27.5a	2.5	32.5a	2.5	NS	49.5a	2.96	48.25a	2.96	NS
Salinity (mg/l)	0.053a	0.28	0.88a	0.28	NS	3.34a	0.33	1.44b	0.33	**	0.03b	0	0.04a	0	***	0.32a	0.15	0.058a	0.15	NS
TDS (ppm)	75a	261.48	950a	261.48	NS	10	0	10	0	NS	30b	0	50a	0	***	107.5a	1.77	110a	1.77	NS

M = Mean; SE = Standard Error; ANOVA = Analysis of variance; * = P<0.05; ** = p<0.01; *** = p<0.001; NS = p>0.05; The means between classes of the same line followed by the same letters don't differ significantly with the threshold of 5%.

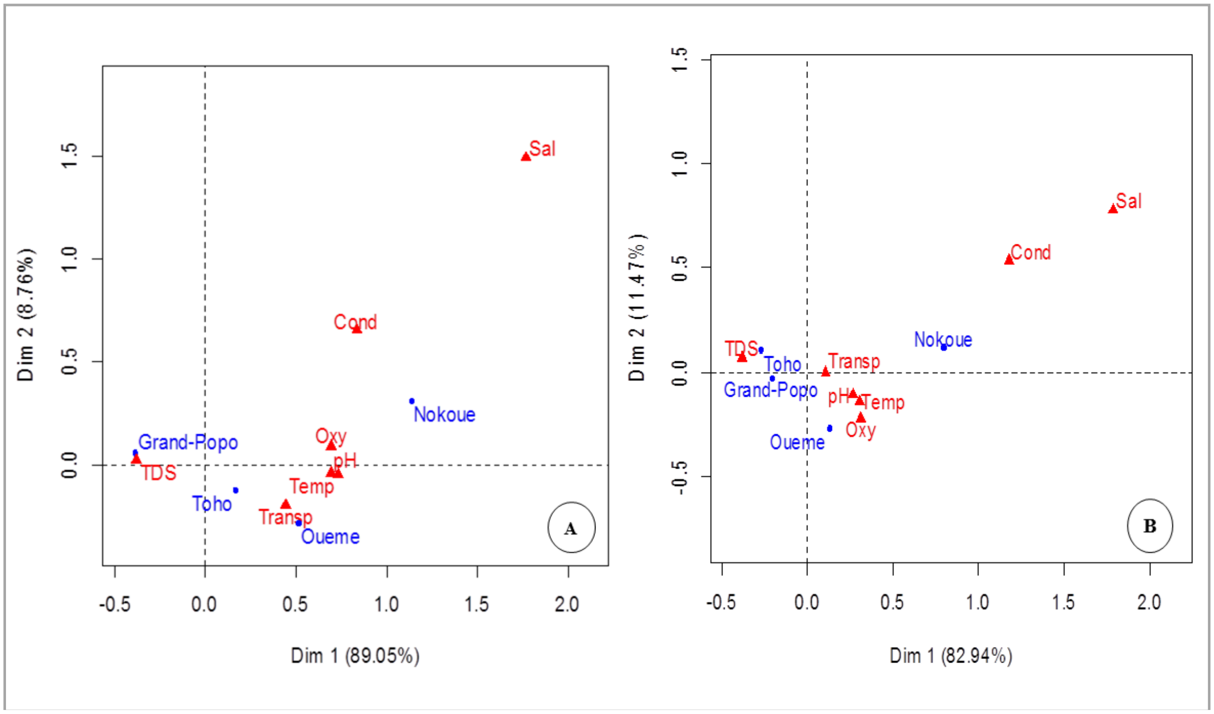

Fig. 3: FCA analysis based on physicochemical variables according to the time of the day (A = morning *vs* B = evening).

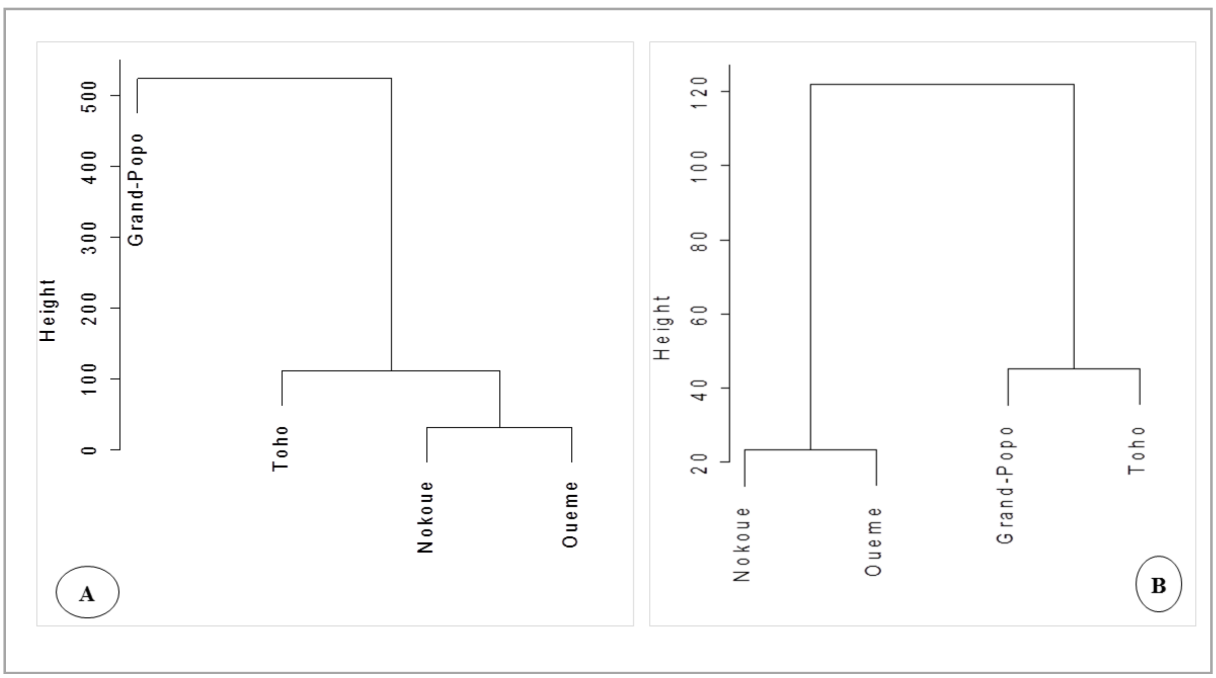

Fig. 4: Numeric classification based on physicochemical factors, showing proximities between *Sarotherodon melanotheron* populations according to the time of the day (A = morning *vs* B = evening).

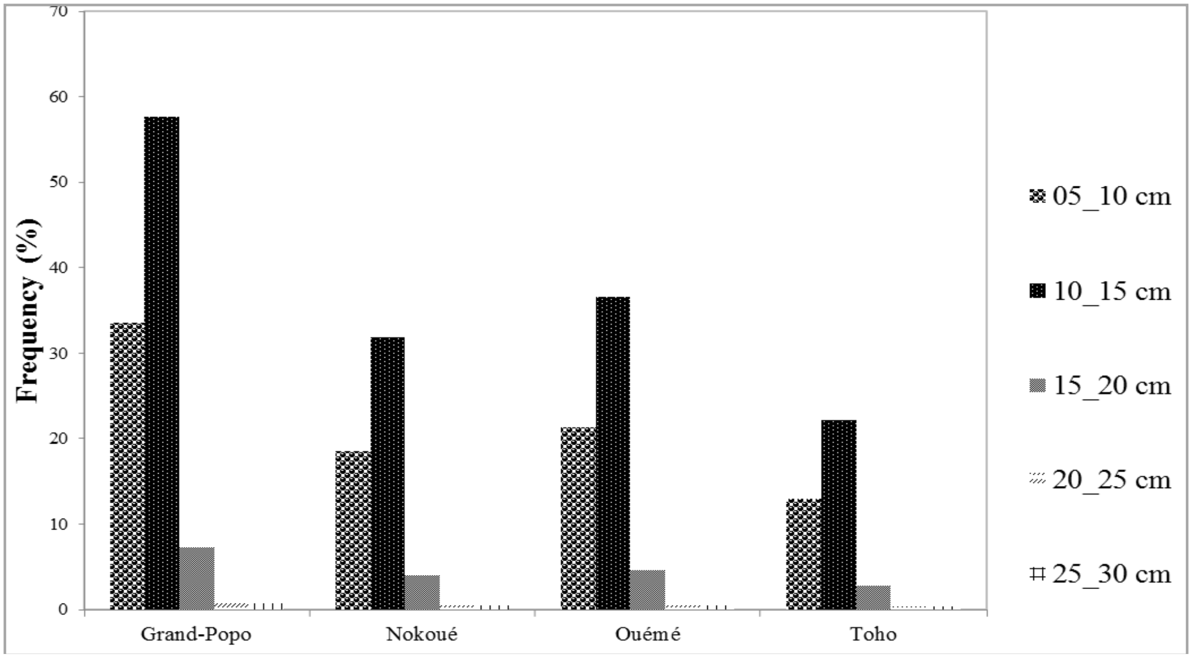

Fig. 5: Fish sizes distribution in the sampled waterways.

Standard Length-Body Height (SL-BH) Relationship

Globally, the body height of *Sarotherodon melanotheron* has been strongly associated to standard length ($p<0.001$; Table 5). Overall, this relationship is linear and the developed equations of regression indicated determination coefficients (R^2) varying from 0.18 to 0.79 among males. For females, the prediction equations of standard length from body height were more precise with R^2 ranging between 0.54 and 0.92. However, the biggest precision of observations has been gotten among females of Ouémé river (R^2=0.92; $p<0.001$).

Table 5: Equations and determination coefficients of the SL-BH relationships by sex in the sampling waterways.

Waterway		**Male**	**Female**
Grand-Popo lagoon	**Equation**	**y=1.321x+4.552**	**y=2.048x+2.479**
	R^2	0.471	0.853
	N	57	80
	Intercept	4.55	2.48
	Slope	1.32	2.05
	RSE	1.92	0.59
	Significativity	***	***
Lake Nokoué	**Equation**	**y=0.114x+11.25**	**y=2.170x+2.361**
	R^2	0.181	0.638
	N	89	92
	Intercept	11.25	2.36
	Slope	0.11	2.17
	RSE	1.31	0.87
	Significativity	***	***
Ouémé river	**Equation**	**y=1.625x+4.465**	**y=2.431x+1.270**
	R^2	0.546	0.918
	N	66	60
	Intercept	4.47	1.27

	Slope	1.63	2.43
	RSE	0.90	0.59
	Significativity	***	***
Lake Toho	**Equation**	**y=1.884x+3.275**	**y=1.219x+5.209**
	R^2	0.79	0.535
	N	86	79
	Intercept	3.28	5.21
	Slope	1.88	1.22
	RSE	0.65	1.04
	Significativity	***	***

*** = p<0.001; RSE = Residual Standard Error; R² = Determination coefficient; N = Effective.

Total Length-Weight (TL-W) Relationship

The regression equations of power type have been developed between the body weight and total length (Table 6). For males, on one hand, b varied from 2.32 to 2.79 with the determination coefficients ranging from 0.77 to 0.93 and on the other hand, from 1.74 to 2.99 for females. For females, the determination coefficients varied from 0.38 to 0.94.

Table 6: Equations and determination coefficients of TL-W relationships per sex.

Waterway		Male	Female
Grand-Popo lagoon	Equation	$y=0.037x^{2.696}$	$y=0.025x^{2.854}$
	R^2	0.93	0.887
	N	57	80
	Logarithmic equation	LogW=2.7LogTL-1.43	LogW=2.9LogTL-1.6
Lake Nokoué	Equation	$y=0.055x^{2.583}$	$y=0.532x^{1.737}$
	R^2	0.788	0.381
	N	89	92
	Logarithmic equation	LogW=2.6LogTL-1.26	LogW=1.7LogTL-0.27
Ouémé river	Equation	$y=0.108x^{2.317}$	$y=0.023x^{2.896}$
	R^2	0.77	0.944
	N	66	60
	Logarithmic equation	LogW=2.3LogTL-0.97	LogW=2.9LogTL-1.64
Lake Toho	Equation	$y=0.031x^{2.786}$	$y=0.018x^{2.991}$
	R^2	0.925	0.942
	N	86	79
	Logarithmic equation	LogW=2.8LogTL-1.51	LogW=3LogTL-1.74

R² = Determination coefficient; N = Effective.

Condition Factor K

Overall waterways, K didn't vary significantly from a sex to another (p>0.05). The smallest value of K was recorded among females of lake Nokoué (1.79) while its strongest value was noted at males of Ouémé river (1.88) (Table 7).

Table 7: Condition coefficient (K) per waterway and sex.

Waterway	Male		Female		Test of significance
	Mean	SD	Mean	SD	
Grand-Popo lagoon	1.87a	0.42	1.87a	0.36	NS
Lake Nokoué	1.81a	0.37	1.79a	0.29	NS
Ouémé river	1.88a	0.42	1.83a	0.23	NS
Lake Toho	1.87a	0.25	1.85a	0.20	NS

SD = Standard deviation, NS = p>0.05, The means between classes of the same line followed by the same letters don't differ significantly with the threshold of 5%.

Metric and Ponderal Parameters

Fishes' body height, head length, snout length, preanal length, prepectoral length, prepelvic length, dorsal-fin base length, pelvic-fin length and caudal peduncle height didn't vary significantly according to the hydrobiological period of sampling (p>0.05). However, the weight, total length, interorbital width, predorsal length, anal-fin base length and dorso-anal length were less important during the rise of the water level than the subsidence (p<0.01). On the other hand, the eye diameter and pectoral-fin length were more important during the rise of the water level than the subsidence (p<0.01) (Table 8).

A part from the body height, prepelvic length and anal-fin base length, all the other parameters varied significantly from a waterway to another. Indeed, the weight was significantly less elevated among *Sarotherodon melanotheron* individuals of Grand-Popo lagoon than those of lake Toho (29.63±2.81 g *vs* 38.28±0.49 g). In the same way, the body weight was also less important at individuals of lake Toho than those of Ouémé river (38.28±1.49 g *vs* 46.61±2.26 g). Furthermore, this ponderal parameter was more elevated at lake Nokoué than the 3 other waterways (p<0.001). The same tendency has been observed for total length, standard length, interorbital width and caudal peduncle height (Table 8).

The head length was significantly more important among individuals of Ouémé river than those of the 3 other waterways (p<0.001). It was, on one hand, more important at lake Nokoué than Grand-Popo lagoon (33.20±0.23%SL *vs* 31.43±0.32%SL) and on the other hand, more elevated at Grand-Popo lagoon than lake Toho (31.43±0.32%SL *vs* 29.1±0.47%SL). The snout length was significantly weaker at individuals of Grand-Popo lagoon than those of Ouémé river and weaker at Ouémé river than lake Nokoué (p<0.05). Furthermore, it was significantly weaker among *Sarotherodon melanotheron* individuals of lake Nokoué than those of lake Toho (11.01±0.12%SL *vs* 11.11±0.49%SL, p<0.05) (Table 8). The eye diameter and dorsal-fin base length were significantly higher at Ouémé river than lake Nokoué (p<0.05). In the same way, they were significantly more elevated to these two waterways than lake Toho and Grand-Popo lagoon. However, they were significantly weaker at Grand-Popo lagoon than lake Toho (6.15±0.14%SL *vs* 6.54±0.43%SL, p<0.05). To lake Toho, the predorsal length was intermediate between Grand-Popo lagoon and Ouémé river (p<0.05). The predorsal length was significantly less elevated at *Sarotherodon melanotheron* individuals of lake Nokoué than those of the 3 other waterways (p<0.001). With regard to the preanal length, it was on one hand, significantly higher at lake Toho (75.58±0.29%SL) than Grand-Popo lagoon (75.06±0.56%SL). It was also significantly higher at individuals of Grand-Popo lagoon than those of Ouémé river (74.01±0.41%SL) (p<0.05). Moreover, it was more important at Ouémé river than lake Nokoué (73.76±0.27%SL) (p<0.05). At Ouémé river, the prepectoral length was intermediate between Grand-Popo lagoon and lake Nokoué (p<0.05). This measurement was weak (p<0.001) at lake Toho than the 3 other waterways (Table 8). The pectoral-fin length was significantly identical between Grand-Popo lagoon and lake Toho (p>0.05). It was weaker to these last two waterways than lake Nokoué and Ouémé river (p<0.05). Furthermore, it was significantly less important at lake Nokoué than Ouémé river (38.94±0.30%SL *vs* 39.37±0.34%SL, p<0.05). The pelvic-fin length was identical (p>0.05) between Grand-Popo lagoon and lake Toho. In the same way, it was more elevated at lake Nokoué than Ouémé river (p<0.05). As for the dorso-anal length, it was on one hand, less elevated at individuals of Grand-Popo lagoon than those of Ouémé river and on the other hand, less important at Ouémé river than lake Toho (p<0.05). Furthermore, it was weaker (p<0.05) at *Sarotherodon melanotheron* individuals of lake Toho than those of lake Nokoué (Table 8).

The body height, head length, eye diameter, interorbital width, predorsal length, preanal length, prepectoral length, prepelvic length, dorsal-fin base length, pectoral-fin length, pelvic-fin length and caudal peduncle height didn't vary significantly between females and males (Table 8). The weight, total length, standard length, snout length and anal-fin base length were significantly less elevated ($p<0.05$) at female individuals than males. On the other hand, the dorso-anal length was significantly less important ($p<0.001$) among males than females (50.54±0.24%SL *vs* 51.69±0.25%SL).

Table 8: Variation of metric and ponderal parameters per sampling period, waterway and sex.

	Period					Waterway									Sex				
	Rise of the water level		Subsidence		ANOVA	Grand-Popo lagoon		Lake Nokoué		Ouémé river		Lake Toho		ANOVA	Female		Male		ANOVA
Variable	**M**	**SE**	**M**	**SE**		**M**	**SE**	**M**	**SE**	**M**	**SE**	**M**	**SE**		**M**	**SE**	**M**	**SE**	
Weight	34.11b	1.31	53.16a	1.61	***	29.63d	2.81	64.78a	1.67	46.61b	2.26	38.28c	1.49	***	43.31b	1.43	48.55a	1.89	*
TL	11.85b	0.18	13.87a	0.14	***	11.01d	0.24	15.26a	0.13	13.14b	0.31	12.45c	0.15	***	12.87b	0.16	13.34a	0.17	*
SL	9.12b	0.12	10.65a	0.10	***	8.57d	0.17	11.6a	0.11	10.15b	0.19	9.57c	0.11	***	9.85b	0.11	10.28a	0.13	**
BH (%SL)	35.39a	0.56	36.70a	0.87	NS	35.26a	0.90	37.79a	1.64	35.35a	0.33	35.66a	0.40	NS	35.82a	0.25	36.59a	1.17	NS
HL (%SL)	31.75a	0.39	31.51a	0.21	NS	31.43c	0.32	33.20b	0.23	33.34a	0.44	29.1d	0.47	***	31.45a	0.30	31.76a	0.26	NS
SnL (%SL)	10.53a	0.36	10.34a	0.16	NS	8.72d	0.16	11.01b	0.12	10.56c	0.43	11.11a	0.49	***	9.91b	0.24	10.97a	0.23	**
ED (%SL)	7.34a	0.06	6.52b	0.24	**	6.15d	0.14	7.15b	0.11	7.87a	0.39	6.54c	0.43	***	6.94a	0.24	6.73a	0.16	NS
IoW (%SL)	8.16b	0.14	8.93a	0.08	***	7.59d	0.13	9.78a	0.07	9.35b	0.14	7.89c	0.16	***	8.55a	0.10	8.73a	0.11	NS
PrDL (%SL)	33.05b	0.31	34.45a	0.23	***	34.92a	0.48	32.96d	0.23	33.87c	0.38	34.12b	0.38	***	33.79a	0.27	34.03a	0.26	NS
PrAL (%SL)	74.67a	0.36	74.62a	0.22	NS	75.06b	0.56	73.76d	0.27	74.01c	0.41	75.58a	0.29	***	74.85a	0.32	74.42a	0.21	NS
PrPL (%SL)	33.88a	0.28	33.74a	0.17	NS	33.39c	0.45	34.61a	0.20	34.25b	0.26	32.99d	0.22	***	33.78a	0.18	33.81a	0.24	NS
PrPeL (%SL)	38.0a	0.21	37.93a	0.25	NS	38.07a	0.34	38.47a	0.21	37.73a	0.29	37.43a	0.44	NS	37.95a	0.25	37.97a	0.23	NS
DL (%SL)	51.59a	0.23	52.01a	0.22	NS	50.71d	0.39	52.29b	0.20	52.88a	0.32	51.79c	0.34	***	51.91a	0.21	51.79a	0.25	NS
AL (%SL)	12.11b	0.13	13.5a	0.30	***	12.19a	0.46	13.44a	0.21	13.14a	0.17	12.98a	0.47	NS	12.49b	0.24	13.47a	0.30	**
PFL (%SL)	38.34a	0.32	36.95b	0.23	***	36.09c	0.48	38.94b	0.30	39.37a	0.34	36.08c	0.30	***	37.80a	0.25	37.15a	0.29	NS
PeFL (%SL)	26.43a	0.23	26.72a	0.25	NS	25.19c	0.30	28.32a	0.21	27.89b	0.35	25.25c	0.42	***	26.34a	0.21	26.9a	0.29	NS
CPH (%SL)	11.54a	0.46	11.51a	0.09	NS	10.50d	0.15	12.54a	0.15	11.98b	0.16	11.02c	0.58	***	11.61a	0.33	11.42a	0.13	NS
DAL (%SL)	50.45b	0.26	51.57a	0.23	**	49.43d	0.31	52.35a	0.24	51.01c	0.40	51.3b	0.40	***	51.69a	0.25	50.54b	0.24	***

*** = $p<0.001$; ** = $p<0.01$; * = $p<0.05$; NS = $p>0.05$; M = Mean ; SE = Standard Error; ANOVA = Analysis of variance; TL = Total Length; SL = Standard Length; HL = Head Length; BH = Body Height; SnL = Snout Length; ED = Eye Diameter; IoW = Interorbital Width; PrDL = Predorsal Length; PrAL = Preanal Length; PrPL = Prepectoral Length; PrPeL = Prepelvic Length; DL = Dorsal-fin base Length; AL = Anal-fin base Length; PFL = Pectoral-Fin Length; PeFL = Pelvic-Fin Length; CPH = Caudal Peduncle Height; DAL = Dorso-Anal Length.

Table 9: Variation of meristic characteristics per sampling period, waterway and sex.

Variable	Waterway													Sex						
	Grand-Popo			Nokoué			Ouémé			Toho			ANOVA	Female			Male			ANOVA
	M	SE	Range	M	SE	Range	M	SE	Range	M	SE	Range		M	SE	Range	M	SE	Range	
DFR	10.9a	0.08	8-13	10.59b	0.06	8-13	10.3c	0.10	9-15	10.59b	0.07	8-13	***	10.52a	0.05	8-13	10.65a	0.06	8-15	NS
DFS	15.54a	0.05	14-17	15.46a	0.04	13-17	15.65a	0.08	11-16	15.29a	0.16	14-17	NS	15.46a	0.03	13-17	15.57a	0.10	11-40	NS
AFR	8.75a	0.08	7-12	8.58b	0.05	7-12	8.41c	0.08	7-12	8.29d	0.06	6-12	***	8.49a	0.04	7-12	8.57a	0.06	6-12	NS
AFS	3a	0	3-3	3.01a	0.01	3-4	2.99a	0	3-3	3a	0.01	2-3	NS	3a	0.00	2-4	3.00a	0.00	3-4	NS
ULLS	21.02a	0.20	14-26	18.96c	0.13	14-27	19.39b	0.13	16-21	18.87d	0.18	13-24	***	19.2b	0.12	13-26	19.97a	0.13	15-18	***
LLLS	11.83b	0.11	8-16	11.92a	0.11	7-17	11.5c	0.15	7-15	11d	0.12	7-18	***	11.55a	0.09	7-16	11.73a	0.09	7-18	NS
PrDS	6.51d	0.15	4-16	7.46b	0.10	4-11	7.83a	0.14	5-10	6.71c	0.21	3-16	***	7.12a	0.10	3-16	7.33a	0.14	4-16	NS
CPS	12.89c	0.21	7-22	13.92a	0.10	10-18	12.98b	0.19	8-16	12.02d	0.15	8-22	***	13.18a	0.11	8-22	13.04a	0.13	7-22	NS
OpS	16.99b	0.61	4-37	14.79c	0.41	4-36	13.05d	0.65	3-29	18.45a	0.44	2-26	***	15.09a	0.38	2-37	15.68a	0.37	2-28	NS
ULGR	18.91a	0.24	10-26	18.29b	0.18	11-28	17.83d	0.24	11-22	18.09c	0.19	11-29	**	17.92b	0.14	10-26	18.66a	0.16	11-29	***

*** = p<0.001; ** = p<0.01; * = p<0.05; NS = p>0.05 ; M = Mean ; SE = Standard Error; ANOVA = Analysis of variance; DFR = Dorsal-Fin Rays; DFS = Dorsal-Fin Spines; AFR = Anal-Fin Rays; AFS = Anal-Fin Spines; ULLS = Upper Lateral Line Scales; LLLS = Lower lateral line scales; PrDS = Pre-Dorsal Scales; CPS = around Caudal Peduncle Scales; OpS = Operculum Scales; ULGR = first branchial arc's Upper and Lower Gill Rakers.

Meristic Parameters

With regard to the waterways, the dorsal-fin rays were on one hand, significantly more elevated at Grand-Popo lagoon (10.9±0.08) than lakes Nokoué and Toho (10.59±0.06 & 10.59±0.07) and on the other hand, higher at these last 2 waterways than Ouémé river (10.3±0.10). However, the dorsal-fin spines and anal-fin spines didn't vary significantly from a waterway to another (Table 9). At lake Nokoué, the anal-fin rays were intermediate with Grand-Popo lagoon and Ouémé river. Furthermore, they were weaker at lake Toho than the 3 other waterways (p<0.001). The upper lateral line scales were on one hand, more important at Grand-Popo than Ouémé river and on the other hand, higher at Ouémé river than lake Nokoué. In the same way, they were significantly higher at lake Nokoué than lake Toho (p<0.001). They varied from 14 to 26, 14 to 27, 16 to 21 and 13 to 24 respectively for *Sarotherodon melanotheron* individuals of Grand-Popo lagoon, lake Nokoué, Ouémé river and lake Toho (Table 9). As for the lower lateral line scales, they were less important at lake Toho than the 3 other waterways. In the same way, they were on one hand, significantly less elevated at Ouémé river than Grand-Popo lagoon and on the other hand, weaker at Grand-Popo lagoon than lake Nokoué (p<0.001). To lake Nokoué, the pre-dorsal scales were intermediate (p<0.05) between Ouémé river and lake Toho. Furthermore, they were significantly higher (p<0.001) at lake Nokoué, Ouémé river and lake Toho than Grand-Popo lagoon. The around caudal peduncle scales were on one hand, significantly more elevated (p<0.05) at lake Nokoué (13.92±0.10) than Ouémé river (12.98±0.19) and on the other hand, higher (p<0.05) at Ouémé river than Grand-Popo lagoon (12.89±0.21).

In the same way, they were also higher at Grand-Popo lagoon than lake Toho (12.02±0.15). The operculum scales varied from 4 to 37, 4 to 36, 3 to 29 and 2 to 26 respectively for Grand-Popo lagoon, lake Nokoué, Ouémé river and lake Toho. At Grand-Popo lagoon, they were intermediate with lake Nokoué and lake Toho ($p<0.05$). In addition, they were weaker ($p<0.001$) at Ouémé river than the 3 other waterways (Table 9). The first branchial arc's upper and lower gill rakers were on one hand, more important at Grand-Popo lagoon than lake Nokoué (18.91±0.24 *vs* 18.29±0.18) and on the other hand, significantly more elevated at lake Nokoué than lake Toho (18.29±0.18 *vs* 18.09±0.19). They were also higher at lake Toho than Ouémé river (18.09±0.19 *vs* 17.83±0.24).

Between all meristic parameters, only the upper lateral line scales and the first branchial arc's upper and lower gill rakers varied significantly according to the sex. Indeed, they were higher among males than females ($p<0.001$) (Table 9).

Correlations between Meristic Parameters

For the meristic counts, the dorsal-fin rays were negatively and highly correlated to the dorsal-fin spines ($r=-0.22$, $p<0.001$). However, they were positively and strongly bound to the anal-fin rays ($r=0.34$, $p<0.001$), upper lateral line scales ($r=0.23$, $p<0.001$), operculum scales ($r=0.27$, $p<0.001$) and the first branchial arc's upper and lower gill rakers ($r=0.16$, $p<0.001$). The dorsal-fin spines were on one hand, positively and weakly bound to the lower lateral line scales and on the other hand, positively and moderately correlated to the upper lateral line scales ($r=0.10$, $p<0.05$ *vs* $r=0.11$, $p<0.01$). A for the anal-fin rays, they were negatively and moderately correlated to the pre-dorsal scales ($r=-0.12$, $p<0.01$). On the other hand, they were positively and strongly ($p<0.001$) correlated respectively to the upper lateral line scales ($r=0.28$), the operculum scales ($r=0.28$) and the first branchial arc's upper and lower gill rakers ($r=0.20$) (Table 10). The upper lateral line scales were positively and highly correlated respectively to the lower lateral line scales ($r=0.24$, $p<0.001$), the operculum scales ($r=0.34$, $p<0.001$) and the first branchial arc's upper and lower gill rakers ($r=0.32$, $p<0.001$). With regard to the lower lateral line scales, they were positively and moderately bound to the around caudal peduncle scales, the operculum scales and the first branchial arc's upper and lower gill rakers ($r=0.13$, $r=0.10$, $r=0.11$, $p<0.01$) respectively. Furthermore, they were strongly ($p<0.001$) correlated to the pre-dorsal scales. This correlation is positive ($r=0.18$). The pre-dorsal scales were negatively and weakly bound to the first branchial arc's upper and lower gill rakers ($r=-0.09$, $p<0.05$). However, they were positively and highly bound to the around caudal peduncle scales ($r=0.22$, $p<0.001$). The around caudal peduncle scales were negatively and strongly correlated to the operculum scales ($r=-0.22$, $p<0.001$). Among *Sarotherodon melanotheron* individuals, the operculum scales were positively and highly correlated to the first branchial arc's upper and lower gill rakers ($r=0.23$, $p<0.001$) (Table 10).

Multivariate Analysis of Metric and Meristic Parameters

Like physicochemical parameters, FCAs and dendograms (Figures 6 & 7) have also been achieved on metric and meristic parameters in order to analyse the possible closeness between the 4 waterways. Thus, for metric parameters, percentages of the variance decreased suddenly, with the first axis explaining 73.41% of the variations between waterways, the second axis 20.25% and the third 6.35%. On the axis 1, the total length, standard length, head length, interorbital width, predorsal length and preanal length permitted to move away Grand-Popo lagoon from lake Nokoué. On the axis 2, the prepectoral length and dorso-anal length allowed to move away Ouémé river out of lake Toho.

For meristic numberings, percentages of the variance also decreased suddenly with the first axis explaining 86.47% of the variations between waterways, the second axis 9.57% and the third 3.98%. On the axis 1, the anal-fin rays, the lower lateral line scales, the pre-dorsal scales, the around caudal peduncle scales and the operculum scales permitted to bring closer lake Nokoué and Ouémé river and to move them away from Grand-Popo lagoon and lake Toho. At the axis 2, the upper lateral line scales allowed to bring closer Grand-Popo lagoon and lake Toho and to move them away out from lake Nokoué and Ouémé river. In short, AFCs and NCs of metric and meristic variables permitted to stand out two groups: the group constituted on one hand, of lake Nokoué and Ouémé river and group constituted on the other hand, of Grand-Popo lagoon and lake Toho.

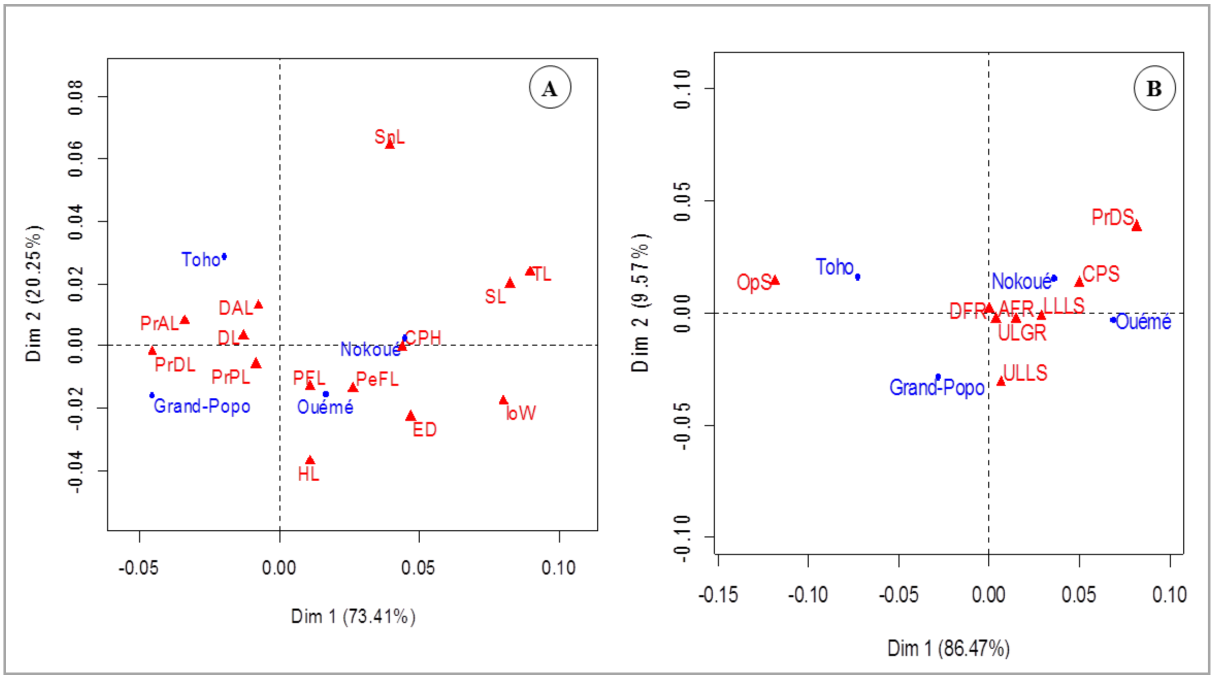

Fig. 6: FCA analysis based on the metric (A) and meristic (B) variables.

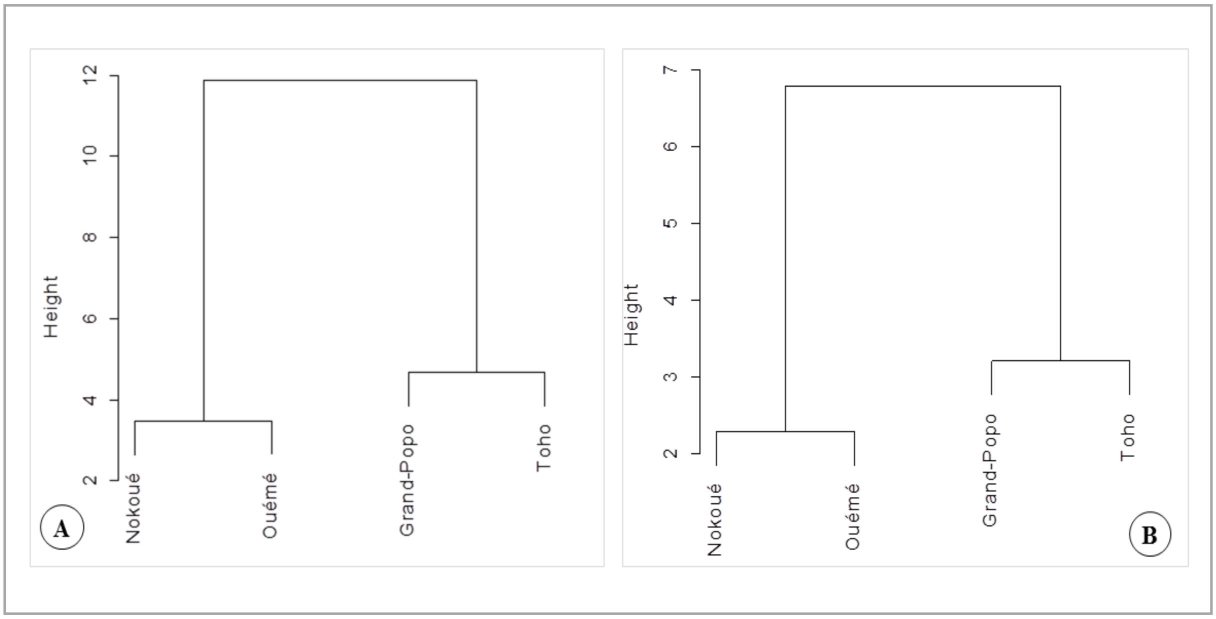

Fig. 7: Dendrogram (Ward's method) based on the metric (A) and meristic (B) variables.

Table 10: Correlations between meristic parameters of *Sarotherodon melanotheron*.

	DFS	AFR	AFS	ULLS	LLLS	PrDS	CPS	OpS	ULGR
DFR	-0.22***	0.34***	-0.02NS	0.23***	0.03NS	-0.07NS	0.01NS	0.27***	0.16***
DFS		0.07NS	0.03NS	0.11**	0.10*	0.00NS	-0.00NS	0.01NS	0.02NS
AFR			-0.02NS	0.28***	0.06NS	-0.12**	0.00NS	0.28***	0.20***
AFS				0.04NS	0.07NS	0.02NS	0.01NS	-0.01NS	0.02NS
ULLS					0.24***	0.02NS	0.01NS	0.34***	0.32***
LLLS						0.18***	0.13**	0.10**	0.11**
PrDS							0.22***	-0.08NS	-0.09*
CPS								-0.22***	0.02NS
OpS									0.23***

*** = p<0.001; ** = p<0.01; * = p<0.05; NS = p>0.05 ; ANOVA = Analysis of variance; DFR = Dorsal-Fin Rays; DFS = Dorsal-Fin Spines; AFR = Anal-Fin Rays; AFS = Anal-Fin Spines; ULLS = Upper Lateral Line Scales; LLLS = Lower lateral line scales; PrDS = Pre-Dorsal Scales; CPS = around Caudal Peduncle Scales; OpS = Operculum Scales; ULGR = first branchial arc's Upper and Lower Gill Rakers.

Discussion

The tilapia species *Sarotherodon melanotheron*, found in the West African estuarine ecosystems, presents a tolerance to various environments that could explain itself by its original physiological features, allowing him important adaptive faculties. In the present study, the physicochemical parameters' values are within the limits for a good survival and production of *Sarotherodon melanotheron* individuals(Ouattara *et al.*, 2003; Lemarié *et al.*, 2004; Panfili *et al.*, 2004; Panfili *et al.*, 2006). Our findings indicate that most of the sampled individuals' sizes ranged between 5 and 15 cm whatever the waterway. These data may indicate overfishing in reference to data in the literature which show that under the right conditions, *Sarotherodon melanotheron* can reach 19.4 cm (Lalèyè, 2006), 19.6 cm (Diouf *et al.*, 2006) and 22 cm (Panfili *et al.*, 2004) in length.

The maximum size of tilapias is more dependent on environmental conditions than any genetic differences (Lacroix, 2004). In the same way, the age and size at first reproduction of most tilapias is variable and is influenced by the environment (Brummett, 1995). *Sarotherodon melanotheron* represents an example of adaptation (to fluctuant salinity environment) acting indirectly on gene product through its promoter (Agnèse *et al.*, 2009). According to Panfili *et al.*, (2004), this tilapia species is able to withstand saltier environments by limiting its growth, reducing the size-at-maturity, and changing its fecundity. The size at maturation was smaller in the more saline environment, for both females and males (170 mm in Gambia and 131 mm in Saloum *vs* 162 in Gambia and 113 mm in Saloum). Similarly, its growth is reduced in the hypersaline environment (Panfili *et al.*, 2004). The standard length of *Sarotherodon melanotheron* individuals has been strongly associated to the body height. This relationship shows that more the fish grows in height, better it grows in size. The relative growth coefficients (b) of total length-weight relationships, varied from 1.74 to 3 for both females and males. This relationship is used to compare the growth of species between different regions (Froese, 2006). When b is equal to 3, isometric pattern of growth occurs, but when b is not equal to 3, allometric pattern of growth occurs, which may be positive if >3 or negative if <3. Among males of Ouémé river and females of lake Nokoué, b<3 showing that the growth of *Sarotherodon melanotheron* is allometric (Le Cren, 1951) and the species grows more in length than weight. Among males of Grand-Popo lagoon, lake Nokoué, lake Toho and females of Grand-Popo lagoon, Ouémé river, lake Toho, the growth is isometric (b=3) (Le Cren, 1951). These values are those generally mentioned in the literature on this species. Indeed, for *Sarotherodon melanotheron*, b value was 2.73 at lake Nokoué (Fagnon, 2011), 3.07 at Ouémé river (Lalèyè, 2006) and 2.67 to lake Toho (Fagnon, 2011). In Côte d'Ivoire, Ouattara *et al.*, (2009) got similar allometric coefficient equals to 2.93 at lake Ayamé. Our results also consistent with the one of Ndimele et al. (2010) (2.38) at Ologe lagoon in Nigeria. In addition, the values gotten for b in this study are similar to those observed by Ecoutin and Albaret (2003) at Ebrié lagoon (2.79) in Côte d'Ivoire. Furthermore, the analyse of a large number of length-weight relationships (L-W) from Fishbase shows that the values of b generally range between 2 and 4, with 90% of values ranging from 2.7 to 3.4 (Froese, 2006). The condition coefficient (K) is used as an indicator of the variability attributable to growth coefficient (b). K (Tesch, 1971) allows to characterize the physiological and nutritional state of fish. In the same way, it permits to appreciate the biologic state, stoutness and plumpness of fishes. In the present study, K did not vary significantly according to the fish's sex ($p>0.05$). This indicates that the species adapts to both brackish and fresh waters. The observed values reveal the good adaptation of this species in these different waterways. Although being naturally adapted to the lagoon environment, *Sarotherodon melanotheron* also tolerates fresh water (Koné and Teugels, 1999). These observations are similar to those made by Panfili *et al.*, (2004) and Ouattara *et al.*, (2009) who underline a good adaptation of this species with growth higher in lake Ayamé than lagoon environment (Gambia and Saloum estuaries). The differences observed at each of our populations maybe due to their habitat, the available food resources, the individuals demographic structure, the selectivity of the fishing gears, the predation, and the waterway's wide, etc.

ANOVAs, FCAs and NCs allowed analysing the 4 *Sarotherodon melanotheron* populations studied. Between the 27 morphological variables, 22 (14 for metric traits and 08 for meristic counts) permit to differentiate significantly these populations. Between metric characters, only the total length, standard length, head length, interorbital width, predorsal length, prepectoral length, preanal length and dorso-anal length permitted to differentiate specifically the 4 waterways. They permitted to bring closer individuals of lake Nokoué and Ouémé river and to discriminate them from those of Grand-Popo lagoon and lake Toho. As for meristic counts, the anal-fin rays, lower lateral line scales, pre-dorsal scales, around caudal peduncle scales, operculum scales and upper lateral line scales allowed to discriminate specifically the individuals of lake Nokoué and Ouémé river and to move them away from those of Grand-Popo lagoon and lake Toho. In the present study, the metric variables are more discriminative than meristic counts. These observations join those of Gourène and Teugels (1993); Amon *et al.*, (2013) who consider these characteristics like a key ecological feature bound to fish habitat. In Côte d'Ivoire, the head length has been mentioned by Adépo-Gourène and Gourène (2008) like the most discriminative features of *Sarotherodon melanotheron*'s natural populations. Fagnon *et al.*, (2013) also did the same remark when characterizing *Sarotherodon melanotheron melanotheron* populations from fresh and brackish waters in Benin. The findings of Gourène and Teugels (1993) also showed metric variables as pertinent in the discrimination of *Oreochromis niloticus* in this case, prepelvic length, prepectoral length, head length, preanal length. For Pante *et al.*, (1988), the most discriminative metric characters in tilapias is head length. According to Huber *et al.*, (1997); Schliewen *et al.*, (2001), for tilapias, eye diameter is one of the most discriminative metric variables. In our study, the most discriminative measurements are: total length, standard length, head length, interorbital width, predorsal length, prepectoral length, preanal length and dorso-anal length. These parameters identified like pertinent, discriminated the studied populations and permitted to consider two groups. The first group constituted by Ouéme river and lake Nokoué and the second including Grand-Popo lagoon and lake Toho. The nuances observed between these populations with regard to some meristic counts can be due to the water quality in these 4 waterways. Chapman *et al.*, (2002) underline that, in the wild, fish from hypoxic areas tend to have larger gills than fish from normoxic environments, which is probably an adaptive response. These differences can also be due to the smallness of the sampled individuals of this study and that is linked to overfishing on these waterways. Of course, the overfishing has for corollary the fishing of individuals of small sizes. Similarly, the significant variations in some metric and meristic features might have occurred as a result of environmental fluctuations, especially water temperature and salinity. For several authors, metric and meristic traits are sensitive to any environmental changes. The variation of some metric (body height, caudal peduncle height, snout length, pectoral-fin length) and meristic describers is phenotypic because they are linked to the environment (Barlow, 2007; Dynes *et al.*, 1999). The influence of these traits in the discrimination of the 4 studied populations justifies the proximity of ecological or environmental factors in these waterways. The proximity observed between Ouémé river and lake Nokoué on one hand, Grand-Popo lagoon and lake Toho on the other hand, could be explained by the geographical proximity of these waterways and the similarity of some ecological factors. Moreover, Omoniyi and Agbon (2008) showed that fresh water populations of *Sarotherodon melanotheron* could be phenotypically separable from brackish water population which was the original source. This remark seems not to be confirmed in the present study considering the closeness observed between our populations. This clean distinction between these populations let also to foretell that these waterways undergo important pressures (overfishing, deterioration of habitats, etc.). It could have an effect therefore on the fish life traits and their availability in large size.

Conclusion

When all's said and done, the study permitted to identify *Sarotherodon melanotheron* populations adapted for brackish environment aquaculture promoting in Benin. It reveals the existence of very important and significantly morphological diversities among individuals. The environmental and ecological factors influence the morphometric variability of this tilapia species. The different groups descended from analyses must be considered, from then on, like different populations not to mix in fish farming. Thus, two populations are differentiated: the first constituted by the individuals of Ouémé river and lake Nokoué and the second represented by individuals of Grand-Popo lagoon and lake Toho. Complementary studies concerning genetic analysis need to be investigated to explain and confirm the genetic basis of variations before a selective breeding programme of the species is initiated.

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References

Adépo-Gourène B, Gourène G (2008). Différentiation morphologique des populations naturelles d’une sous espèce de tilapia Sarotherodon melanotheron melanotheron Rüppell, 1852 (Teleostei; Cichlidae) de Côte D’ivoire. Sci. Nat., 5(1): 15-27.

Agnèse JF, Adépo-Gourène B, Nyingi D (2009). Functional microsatellite and possible selective sweep in natural populations of the Black-Chinned tilapia Sarotherodon melanotheron (Teleostei, Cichlidae). Mar. Genom., 1(3-4): 103-107.

Amon YN, Yao K, Ouattara M, Kouman YC, Atse BC (2013). Morphologie des hybrides issus du croisement intergénérique entre Oreochromis niloticus (Linnaeus, 1758) et Sarotherodon melanotheron (Rüppel, 1852). J. Appl. Biosc., 69: 5475-5486.

Barlow GW (2007). Causes and significance of morphological variation in fishes. Syst. Zool., 10(3): 105-117.

Brummett RE (1995). Environmental regulation of sexual maturation and reproduction in tilapia. Rev. Fish. Sci., 3(3): 231-348.

Chapman LJ, Chapman CA, Nordlie FG, Rosenberger AE (2002). Physiological refugia: swamps, hypoxia tolerance and maintenance of fish diversity in the lake Victoria region. Compar. Biochem. Physiol., 133(3): 421-437.

CountryStat (2016). Base de données statistiques de la FAO. Rome, Italy.

Crispo E, Chapman LJ (2008). Population genetic structure across dissolved oxygen regimes in an African Cichlid fish. Mol. Ecol., 17(9): 2134-2148.

Diouf K, Panfili J, Labonne M, Aliaume C, Tomás J, Do Chi T (2006). Effects of salinity on strontium: Calcium ratios in the otoliths of the West African Black-Chinned tilapia

Sarotherodon melanotheron in a hypersaline estuary. Env. Biol. Fish., 77(1): 9-20.

Dunz AR, Schliewen UK (2010). Description of a tilapia (Coptodon) species flock of lake Ejagham (Cameroon), including a redescription of Tilapia deckerti Thys van Den Audenaerde, 1967 (Perciformes, Cichlidae). Spix., 33(2): 251-280.

Dynes J, Magnan P, Bernatchez L, Rodriguez MA (1999). Genetic and morphological variation between two forms of lacustrine Brook Charr. J. Fish Biol., 54: 955-972.

Ecoutin JM, Albaret JJ (2003). Relation longueur-poids pour 52 espèces de poissons des estuaires et lagunes de l'Afrique de l'Ouest. Cyb., 27(1): 3-9.

Fagnon MS (2011). Caractérisation morphologique et écologique des populations de S. melanotheron Rüppell, 1852 (Teleostei; Cichlidae) en eaux douces et en eaux saumâtres au Bénin. Master thesis, Université d'Abomey-Calavi, Benin.

Fagnon MS, Chikou A, Youssao I, Laleye P (2013). Caractérisation morphologique des populations de Sarotherodon melanotheron (Pisces, Cichlidae) en eaux douces et saumâtres au sud Bénin. Int. J. Biol. Chem. Sci., 7(2): 619-630.

FAO (2008). Vue générale du secteur des pêches national de la République du Bénin. Rome, Italy.

FAO (2014). The state of world fisheries and aquaculture. FAO, Rome, Italy.

Froese R (2006). Cube law, condition factor, and weight-length relationship: History, meta-analysis and recommendations. J. Appl. Ichtyol., 22(4): 241-253.

Gourène G, Teugels GG (1993). Différenciation morphologique de souches des tilapias Oreochromis niloticus et O. aureus (Teleostei; Cichlidae) utilisées en pisciculture. Cyb., 17(4): 343-355.

Huber R, van Staaden MJ, Kaufman LS, Liem KF (1997). Microhabitat use, trophic patterns, and, the evolution of brain structure in African Cichlids. Brain Beh. Evol., 50(3): 167-182.

Koné T, Teugels GG (1999). Données sur la reproduction d'un tilapia estuarien (Sarotherodon melanotheron) isolé dans un lac de barrage Ouest-Africain. Aquat. Liv. Res., 12(4): 289-293.

Lacroix E (2004). Pisciculture en zone tropicale. GTZ & GFA Terra Systems, Hamburg Allemagne.

Lalèyè PA (2006). Length-weight and length-length relationships of fishes from the Ouémé river in Bénin (West Africa). J. Appl. Ichthyol., 22(4): 330-333.

Le Cren ED (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the Perch (Perca fluviatilis). J. Anim. Ecol., 20(2): 201-219.

Lemarié G, Baroiller JF, Clota F, Lazard J, Dosdat A (2004). A simple test to estimate the salinity resistance of fish with specific application to niloticus O, melanotheron S. Aquacul., 240(1-4): 575-587.

MAEP/JICA (2009). Etude de la promotion de l'aquaculture continentale pour le developpement rural en Republique du Benin: Rapport final. DPH/MEAP, Cotonou, Bénin.

Ndimele PE, Kumolu- Johnson CA, Aladetohun NF, Ayorinde OA (2010). Length-weight relationship, condition factor and dietary composition of Sarotherodon melanotheron Rüppell, 1852 (Pisces: Cichlidae) in Ologe lagoon, Lagos, Nigeria. Agricul. Biol. J. North Amer., (4): 584-590.

Omoniyi IT, Agbon AO (2008). Morphometric variations in Sarotherodon melanotheron (Pisces: Cichlidae) from brackish and fresh water habitats in South-Western Nigeria. West Afric. J. Appl. Ecol., 12(1): 1-5.

Ouattara NI, Iftime A, Mester LE (2009). Age et croissance de deux espèces de Cichlidae (Pisces): Oreochromis niloticus (Linnaeus, 1758) et Sarotherodon melanotheron Rüppell, 1852 du lac de barrage d'Ayamé (Côte d'Ivoire, Afrique de l'Ouest). Trav. Mus. Nat. Hist. Nat. «Grigore Antipa», LII: 313-324.

Ouattara NI, N'Douba V, Kone T, Snoeks J, Philippart JC (2005). Performances de croissance d'une souche isolée du tilapia estuarien Sarotherodon melanotheron (Perciformes, Cichlidae) en bassins en béton, en étangs en terre et en cages flottantes. A. Univ. Marien Ngouabi, 6(1): 113-119.

Ouattara NI, Teugels GG, N'Douba V, Philippart JC (2003). Aquaculture potential of the Black-Chinned tilapia, Sarotherodon melanotheron (Cichlidae). Comparative study of the effect of stocking density on growth performance of landlocked and natural populations under cage culture conditions in lake Ayame (Côte d'Ivoire). Aquacult., Res., 34(13): 1223-1229.

Ouattara N'G, Ouattara S, Bamba Y, Yao K (2014). Influence de la salinité sur la structure des branchies et l'ultrastructure des ionocytes chez le tilapia Sarotherodon melanotheron heudelotii provenant d'un estuaire hypersalé (Saloum, Sénégal). J. Appl. Biosci., 79: 6808-6817.

Panfili J, Mbow A, Durand JD, Diop K, Diouf K, Thior D, Ndiaye P, Laë R (2004). Influence of salinity on the life-history traits of the West African Black-Chinned tilapia (Sarotherodon melanotheron): Comparison between the Gambia and Saloum estuaries. Aquat. Liv. Res., 17(1): 65-74.

Panfili J, Thior D, Ecoutin J-M, Ndiaye P, Albaret JJ (2006). Influence of salinity on the size at maturity for fish species reproducing in contrasting West African estuaries. J. Fish Biol., 69(1): 95-113.

Pante MJR, Lester LJ, Pullin RSV (1988). A preliminary study on the use of canonical discriminant analysis of morphometric characters to identify cultured tilapias. In 2nd Int. Symp. Tilapia Aquacul., ICLARM, 251-257, Manila, Philippines.

Paugy D, Lévêque C, Teugels GG (2004). Faune des poissons d'eau douce et saumâtre d'Afrique de l'Ouest. 2nd Ed., Faune et flore tropicales, Paris, France.

Schliewen U, Rassmann K, Markmann M, Markert J, Kocher T, Tautz D (2001). Genetic and ecological divergence of a monophyletic cichlid species pair under fully sympatric conditions in lake Ejagham, Cameroon. Mol. Ecol., 10(6): 1471-1488.

Sohou Z, Houedjissin RC, Ahoyo NRA (2009). La pisciculture au Bénin : De la tradition à la modernisation. Bull. Rech. Agro. Ben., 66(12): 48-59.

Stiassny MLJ, Teugels GG, Hopkins CD (2007). Poissons d'eaux douces et saumâtres de basse Guinée, Ouest de l'Afrique Centrale. IRD & AMNH, Paris, France.

Tesch W (1971). Age and growth. In Methods for assessments of fish production in freshwaters, Ricke WE, Ed., 97-130, Oxford, England.

Toguyeni A, Bezault E, Rognon X (2003). Genetic structure analysis of the Nile Tilapia (Oreochromis niloticus) using microsatellite markers. In Paradi Symposium, Cotonou, Benin.